2 Methodology of Analysis

Absent clarity in the FCC Rules for BoPL and a limited disclosure by the BoPL industry, the operating parameters of the systems modeled were based upon studying various publically-available documents and from "backing into certain parameters" using bits of FCC Part 15. There was a lack of specificity for certain critical parameters which necessitated making educated guesses. Throughout this report the assumptions made or collected will be identified as such.

2.1 Discussion of Computer Modeling

Version 4 of the Numerical Electromagnetic Computation (NEC4) program from Lawrence-Livermore Laboratories was used to model the ingress of BoPL into television receiving antennas. NEC4 uses the Method of Moments (MoM) technique which is described in *Electromagnetic* by John Kraus (Fourth Edition, McGraw-Hill).

As typical receiving antennas and the powerlines carrying the BoPL signal are within the near-field of each other, simple square-law attenuation cannot be used to calculate the power induced into a television receiving antenna. This is one reason why NEC4 was used; it can deal with the near-field effects.

To simulate television receiving antennas, half-wave dipoles were placed in the simulations at various locations approximately 18 to 33 feet from the power lines at a height of 30 feet above ground level. Based on the houses in the neighborhoods surveyed, this is where a television antenna would logically be mounted.

Using NEC4 the power in the various dipoles was computed.

2.2 Powerline Injection Level

This study assumes an injection level of the data signal into the medium-voltage powerline of -56 dBm/Hz. Channels 2, 3, 4, and 5 were each investigated by means of a single CW tone at the center of each channel allocation. The injection level into the power line of the CW tone was -56 dBm.

This value provided fields that were compliant with Part 15 *when measured in a one hertz bandwidth.* Appendix A provides tabular summaries and graphical presentations of the fields surrounding the power lines from 1 to 4 m AGL on channels 2, 3, 4, and 5; the white areas on the graphs indicate areas excluded from compliance measurement by FCC Part 15.

In all cases the BoPL signal was injected into one phase only. No analysis was conducted using BoPL excitation on multiple AC phases; however, the resultant radiated field from multiple phase excitation would be expected to be higher than the single phase excitation case.

2.3 BoPL Signal Characteristics

There appear to be two types of modulation used in the various BoPL systems: OFDM and DSSS. There seems to be no fixed frequency plan for either type of modulation. Absent any documentation from the BoPL industry, the assumption is made that the occupied bandwidth of the BoPL signal exceeds the 6 MHz bandwidth of a television signal.

3 Results

Tables 1 and 2 show the power induced *by a single CW tone* into the various dipoles located near the modeled power lines carrying BoPL signals. It is important to note that the input power shown for each channel in the these two tables is a single, unmodulated carrier at band center modeling BoPL excitation at a nominal input power of -56 dBm. See Figures 1 and 17 for the locations of Dipoles 1 2, and 3 for each of the two sections modeled.

Again it should be stressed that the receiving dipoles were located in places where one would be expected to place an outdoor antenna given the location of the houses in the neighborhoods.

Ch 2 – 57 MHz			
input power =	-56.07 dBm		
	current (A)	power (W)	power (dBm)
Dipole 1	7.29E-08	3.83E-13	-94.17
Dipole 2	7.64E-09	4.20E-15	-113.76
Dipole 3	4.72E-09	1.60E-15	-117.95
Ch 3 – 63 MHz			
input power =	-56.02 dBm		
	current (A)	power (W)	power (dBm)
Dipole 1	2.72E-08	5.33E-14	-102.74
Dipole 2	7.10E-09	3.63E-15	-114.40
Dipole 3	3.84E-09	1.06E-15	-119.74
Ch 4 – 69 MHz			
input power =	-56.06 dBm		
	current (A)	power (W)	power (dBm)
Dipole 1	1.50E-08	1.62E-14	-107.90
Dipole 2	2.55E-09	4.68E-16	-123.30
Dipole 3	6.67E-09	3.20E-15	-114.94
Ch 5 – 79 MHz			
input power =	-56.07 dBm		
	current (A)	power (W)	power (dBm)
Dipole 1	3.19E-08	7.33E-14	-101.35
Dipole 2	2.05E-08	3.03E-14	-105.19
Dipole 3	1.40E-07	1.41E-12	-88.50

Table 1: Signal Coupled Into Dipoles for West Los Angeles Section

Ch 2 – 57 MHz			
Input Power =	-56.09 dBm		
	Current (A)	Power (W)	Power (dBm)
Dipole 1	2.59E-08	4.83E-14	-103.16
Dipole 2	1.19E-07	1.02E-12	-89.92
Dipole 3	9.29E-08	6.21E-13	-92.07
Ch 3 – 63 MHz			
Input Power =	-56.04 dBm		
	Current (A)	Power (W)	Power (dBm)
Dipole 1	9.63E-09	6.68E-15	-111.75
Dipole 2	8.48E-08	5.18E-13	-92.86
Dipole 3	6.79E-08	3.32E-13	-94.79
Ch 4 – 69 MHz			
Input power =	-56.00 dBm		
	Current (A)	Power (W)	Power (dBm)
Dipole 1	3.27E-08	7.70E-14	-101.14
Dipole 2	1.41E-07	1.43E-12	-88.44
Dipole 3	1.61E-07	1.87E-12	-87.29
Ch 5 – 79 MHz			
Input Power =	-56.04 dBm		
	Current (A)	Power (W)	Power (dBm)
Dipole 1	2.39E-08	4.11E-14	-103.86
Dipole 2	2.05E-07	3.03E-12	-85.19
Dipole 3	1.19E-07	1.02E-12	-89.92

Table 2: Signal Coupled Into Dipoles for Redondo Beach Section

3.1 Bandwidth Corrections

As the modeling of the BoPL ingress into a dipole uses a single CW tone at band center, corrections have to be made for the actual bandwidths of the BoPL signals and for a 6 MHz television channel. Absent any other data it is assumed that the BoPL spectrum completely overlaps the television channel bandwidth.

In the DSSS case, we can easily calculate the Aggregated Power Increase in a 6 MHz television allocation over the power per unit hertz as 67.8 dB ($10\ log(6 \times 10^6)$).

In the case of OFDM we must estimate the number of individual carriers that will occupy a 6 MHz television channel. The following table shows the increase in in-band power that might be encountered for different OFDM frequency plans:

OFDM Carrier Spacing	Number of Carriers in 6 MHz	Aggregated Power Increase
1 kHz	6000	37.78 dB
10 kHz	600	27.78 dB
50 kHz	120	20.79 dB
100 kHz	60	17.78 dB

Table 3: OFDM Carriers and Aggregated Power Increases

3.2 D/U Table Explanation

Tables 4 through 13 show the D/U ratios for different Aggregated Power Increases and Desired Field Strengths. For instance, Table 4 (West Los Angeles) says that dipoles experiencing a television field strength of 28 dB$\mu V/m$ will have the indicated D/U ratios shown in the Table. The left-hand column shows the various BoPL induced powers in the dipoles per Table 1. The other columns show the D/U ratios for the various Aggregated Power Increases calculated in Section 3.1.

Without knowing the exact nature of the BoPL signals, one cannot state the exact maximum tolerable D/U ratio for successful ATSC reception. However, one can estimate a reasonable number from the

ATSC Planning Factor D/U ratio for co-channel interference of 15 dB (DTV-into-DTV). Entries in Tables 4 through 13 less than 15 dB are shown in red to indicate a high probability of unsuccessful reception.

3.3 West Los Angeles D/U Tables

Tables 4 through 8 show the D/U ratios for various values of Desired field strength from 28 to 68 dB$\mu V/m$ in 10 dB$\mu V/m$ increments. The Aggregated Power Adjustment Values come from Section 3.1.

			D Field =	28	dB$\mu V/m$
BoPL Dipole Power					
-123.30	-28.3	1.7	11.7	18.7	21.7
-119.74	-31.86	-1.86	8.14	15.14	18.14
-117.95	-33.65	-3.65	6.35	13.35	16.35
-114.94	-36.66	-6.66	3.34	10.34	13.34
-114.40	-37.2	-7.2	2.8	9.8	12.8
-113.76	-37.84	-7.84	2.16	9.16	12.16
-107.90	-43.7	-13.7	-3.7	3.3	6.3
-105.19	-46.41	-16.41	-6.41	0.59	3.59
-102.74	-48.86	-18.86	-8.86	-1.86	1.14
-101.35	-50.25	-20.25	-10.25	-3.25	-0.25
-94.17	-57.43	-27.43	-17.43	-10.43	-7.43
-88.50	-63.1	-33.1	-23.1	-16.1	-13.1
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 4: D/U Ratios – West Los Angeles – Desired Signal is 28 dB$\mu V/m$

			D Field =	38	dB$\mu V/m$
BoPL Dipole Power					
-123.30	-18.3	11.7	21.7	28.7	31.7
-119.74	-21.86	8.14	18.14	25.14	28.14
-117.95	-23.65	6.35	16.35	23.35	26.35
-114.94	-26.66	3.34	13.34	20.34	23.34
-114.40	-27.2	2.8	12.8	19.8	22.8
-113.76	-27.84	2.16	12.16	19.16	22.16
-107.90	-33.7	-3.7	6.3	13.3	16.3
-105.19	-36.41	-6.41	3.59	10.59	13.59
-102.74	-38.86	-8.86	1.14	8.14	11.14
-101.35	-40.25	-10.25	-0.25	6.75	9.75
-94.17	-47.43	-17.43	-7.43	-0.43	2.57
-88.50	-53.1	-23.1	-13.1	-6.1	-3.1
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 5: D/U Ratios – West Los Angeles – Desired Signal is 38 dB$\mu V/m$

			D Field =	48	dB$\mu V/m$
BoPL Dipole Power					
-123.30	-8.3	21.7	31.7	38.7	41.7
-119.74	-11.86	18.14	28.14	35.14	38.14
-117.95	-13.65	16.35	26.35	33.35	36.35
-114.94	-16.66	13.34	23.34	30.34	33.34
-114.40	-17.2	12.8	22.8	29.8	32.8
-113.76	-17.84	12.16	22.16	29.16	32.16
-107.90	-23.7	6.3	16.3	23.3	26.3
-105.19	-26.41	3.59	13.59	20.59	23.59
-102.74	-28.86	1.14	11.14	18.14	21.14
-101.35	-30.25	-0.25	9.75	16.75	19.75
-94.17	-37.43	-7.43	2.57	9.57	12.57
-88.50	-43.1	-13.1	rx-3.1	3.9	6.9
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 6: D/U Ratios – West Los Angeles – Desired Signal is 48 dB$\mu V/m$

			D Field =	58	dB$\mu V/m$
BoPL Dipole Power					
-123.30	1.7	31.7	41.7	48.7	51.7
-119.74	-1.86	28.14	38.14	45.14	48.14
-117.95	-3.65	26.35	36.35	43.35	46.35
-114.94	-6.66	23.34	33.34	40.34	43.34
-114.40	-7.2	22.8	32.8	39.8	42.8
-113.76	-7.84	22.16	32.16	39.16	42.16
-107.90	-13.7	16.3	26.3	33.3	36.3
-105.19	-16.41	13.59	23.59	30.59	33.59
-102.74	-18.86	11.14	21.14	28.14	31.14
-101.35	-20.25	9.75	19.75	26.75	29.75
-94.17	-27.43	2.57	12.57	19.57	22.57
-88.50	-33.1	-3.1	6.9	13.9	16.9
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 7: D/U Ratios – West Los Angeles – Desired Signal is 58 dB$\mu V/m$

			D Field =	68	dB$\mu V/m$
BoPL Dipole Power					
-123.30	11.7	41.7	51.7	58.7	61.7
-119.74	8.14	38.14	48.14	55.14	58.14
-117.95	6.35	36.35	46.35	53.35	56.35
-114.94	3.34	33.34	43.34	50.34	53.34
-114.40	2.8	32.8	42.8	49.8	52.8
-113.76	2.16	32.16	42.16	49.16	52.16
-107.90	-3.7	26.3	36.3	43.3	46.3
-105.19	-6.41	23.59	33.59	40.59	43.59
-102.74	-8.86	21.14	31.14	38.14	41.14
-101.35	-10.25	19.75	29.75	36.75	39.75
-94.17	-17.43	12.57	22.57	29.57	32.57
-88.50	-23.1	6.9	16.9	23.9	26.9
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 8: D/U Ratios – West Los Angeles – Desired Signal is 68 dB$\mu V/m$

3.4 Redondo Beach D/U Tables

Tables 9 through 13 show the D/U ratios for various values of Desired field strength from 28 to 68 dB$\mu V/m$ in 10 dB$\mu V/m$ increments. The Aggregated Power Adjustment Values come from Section 3.1.

			D Field =	28	dB$\mu V/m$
BoPL Dipole Power					
-111.75	-39.85	-9.85	0.15	7.15	10.15
-103.86	-47.74	-17.74	-7.74	-0.74	2.26
-103.16	-48.44	-18.44	-8.44	-1.44	1.56
-101.14	-50.46	-20.46	-10.46	-3.46	-0.46
-94.79	-56.81	-26.81	-16.81	-9.81	-6.81
-92.96	-58.64	-28.64	-18.64	-11.64	-8.64
-92.07	-59.53	-29.53	-19.53	-12.53	-9.53
-89.92	-61.68	-31.68	-21.68	-14.68	-11.68
-88.44	-63.16	-33.16	-23.16	-16.16	-13.16
-87.29	-64.31	-34.31	-24.31	-17.31	-14.31
-85.19	-66.41	-36.41	-26.41	-19.41	-16.41
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 9: D/U Ratios – Redondo Beach – Desired Signal is 28 dB$\mu V/m$

			D Field =	38	dB$\mu V/m$
BoPL Dipole Power					
-111.75	-29.85	0.15	10.15	17.15	20.15
-103.86	-37.74	-7.74	2.26	9.26	12.26
-103.16	-38.44	-8.44	1.56	8.56	11.56
-101.14	-40.46	-10.46	-0.46	6.54	9.54
-94.79	-46.81	-16.81	-6.81	0.19	3.19
-92.96	-48.64	-18.64	-8.64	-1.64	1.36
-92.07	-49.53	-19.53	-9.53	-2.53	0.47
-89.92	-51.68	-21.68	-11.68	-4.68	-1.68
-88.44	-53.16	-23.16	-13.16	-6.16	-3.16
-87.29	-54.31	-24.31	-14.31	-7.31	-4.31
-85.19	-56.41	-26.41	-16.41	-9.41	-6.41
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 10: D/U Ratios – Redondo Beach – Desired Signal is 38 dB$\mu V/m$

			D Field =	48	dB$\mu V/m$
BoPL Dipole Power					
-111.75	-19.85	10.15	20.15	27.15	30.15
-103.86	-27.74	2.26	12.26	19.26	22.26
-103.16	-28.44	1.56	11.56	18.56	21.56
-101.14	-30.46	-0.46	9.54	16.54	19.54
-94.79	-36.81	-6.81	3.19	10.19	13.19
-92.96	-38.64	-8.64	1.36	8.36	11.36
-92.07	-39.53	-9.53	0.47	7.47	10.47
-89.92	-41.68	-11.68	-1.68	5.32	8.32
-88.44	-43.16	-13.16	-3.16	3.84	6.84
-87.29	-44.31	-14.31	-4.31	2.69	5.69
-85.19	-46.41	-16.41	-6.41	0.59	3.59
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 11: D/U Ratios – Redondo Beach – Desired Signal is 48 dB$\mu V/m$

			D Field =	58	dB$\mu V/m$
BoPL Dipole Power					
-111.75	-9.85	20.15	30.15	37.15	40.15
-103.86	-17.74	12.26	22.26	29.26	32.26
-103.16	-18.44	11.56	21.56	28.56	31.56
-101.14	-20.46	9.54	19.54	26.54	29.54
-94.79	-26.81	3.19	13.19	20.19	23.19
-92.96	-28.64	1.36	11.36	18.36	21.36
-92.07	-29.53	0.47	10.47	17.47	20.47
-89.92	-31.68	-1.68	8.32	15.32	18.32
-88.44	-33.16	-3.16	6.84	13.84	16.84
-87.29	-34.31	-4.31	5.69	12.69	15.69
-85.19	-36.41	-6.41	3.59	10.59	13.59
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 12: D/U Ratios – Redondo Beach – Desired Signal is 58 dB$\mu V/m$

			D Field =	68	dB$\mu V/m$
BoPL Dipole Power					
-111.75	0.15	30.15	40.15	47.15	50.15
-103.86	-7.74	22.26	32.26	39.26	42.26
-103.16	-8.44	21.56	31.56	38.56	41.56
-101.14	-10.46	19.54	29.54	36.54	39.54
-94.79	-16.81	13.19	23.19	30.19	33.19
-92.96	-18.64	11.36	21.36	28.36	31.36
-92.07	-19.53	10.47	20.47	27.47	30.47
-89.92	-21.68	8.32	18.32	25.32	28.32
-88.44	-23.16	6.84	16.84	23.84	26.84
-87.29	-24.31	5.69	15.69	22.69	25.69
-85.19	-26.41	3.59	13.59	20.59	23.59
	67.8	**37.8**	**27.8**	**20.8**	**17.8**
		Aggregated	Power	Increase	

Table 13: D/U Ratios – Redondo Beach – Desired Signal is 68 dB$\mu V/m$

4 Conclusions

BoPL signals on low-VHF frequencies have the very real capability of making television reception impossible. This is true except where the the Desired signal strength is strong enough to "overcome" the BoPL signals. Additionally it should be noted that the extent of the loss of service to television will depend on the modulation type being used on the BoPL system.

Appendix

A FCC Part 15 Compliance Information

A.1 West Los Angeles Section

Ch 2 – 57 MHz		
average near electric field	20.09	$\mu V/m$
maximum near electric field	146.77	$\mu V/m$
minimum near electric field	0.950	$\mu V/m$
percent compliant	99.63	%
Ch 3 – 63 MHz		
average near electric field	9.70	$\mu V/m$
maximum near electric field	43.86	$\mu V/m$
minimum near electric field	0.463	$\mu V/m$
percent compliant	100.00	%
Ch 4 – 69 MHz		
average near electric field	6.20	$\mu V/m$
maximum near electric field	25.53	$\mu V/m$
minimum near electric field	0.359	$\mu V/m$
percent compliant	100.00	%
Ch 5 – 79 MHz		
average near electric field	87.28	$\mu V/m$
maximum near electric field	939.83	$\mu V/m$
minimum near electric field	4.40	$\mu V/m$
percent compliant	71.55	%

Table 14: Compliance Data for West Los Angeles Section ("percent compliant" refers to the number of points below 90 $\mu V/m$ out of the entire set of points analyzed. The set of points analyzed includes all of those shown in the following figures for the four planes at 1 m, 2 m, 3 m, and 4 m AGL. The points that are closer than 10 m to any part of the network structure were not included in the "percent compliant" value.)

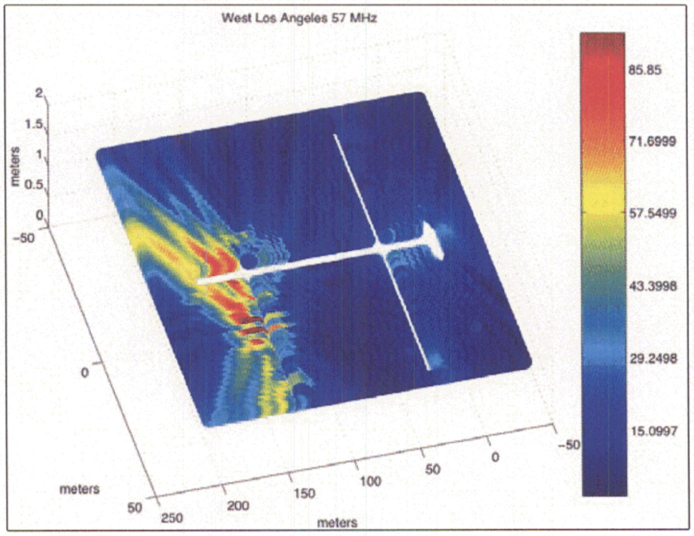

Figure 36: West Los Angeles–1 m AGL–Channel 2–Field in $\mu V/m$

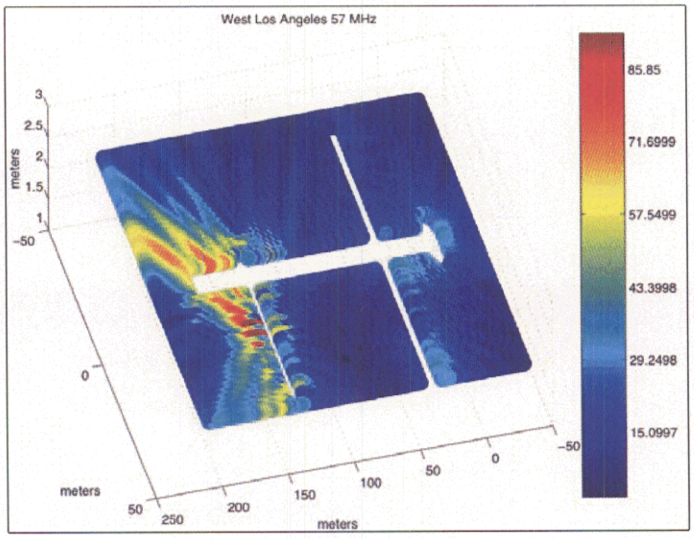

Figure 37: West Los Angeles–2 m AGL–Channel 2–Field in $\mu V/m$

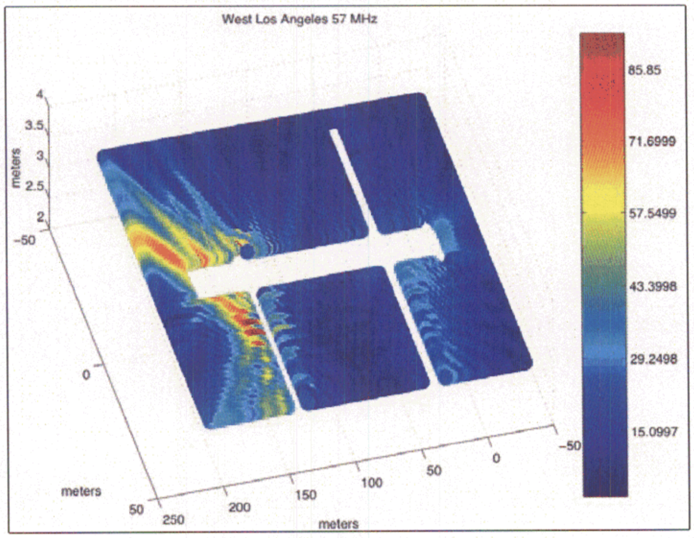

Figure 38: West Los Angeles–3 m AGL–Channel 2–Field in $\mu V/m$

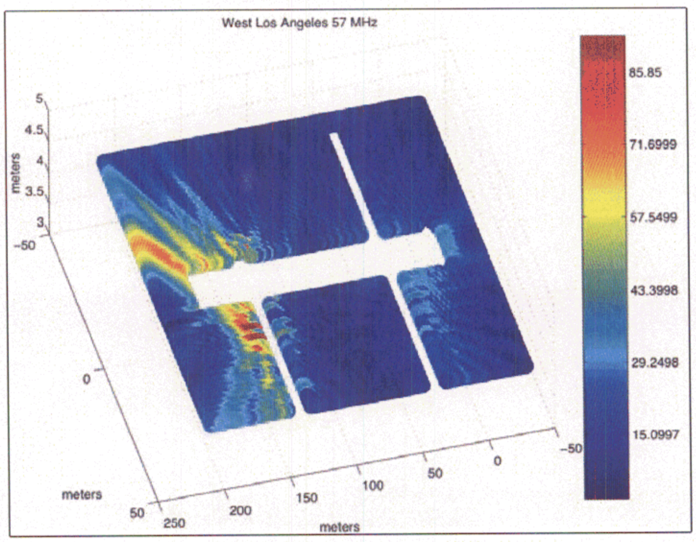

Figure 39: West Los Angeles–4 m AGL–Channel 2–Field in $\mu V/m$

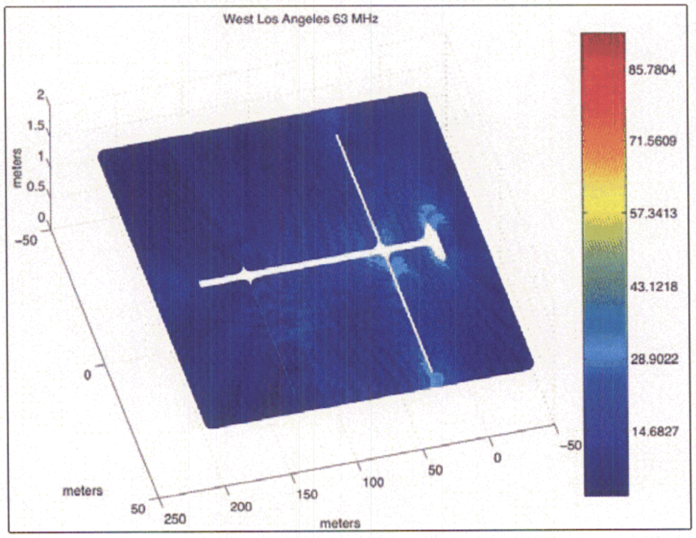

Figure 40: West Los Angeles–1 m AGL–Channel 3–Field in $\mu V/m$

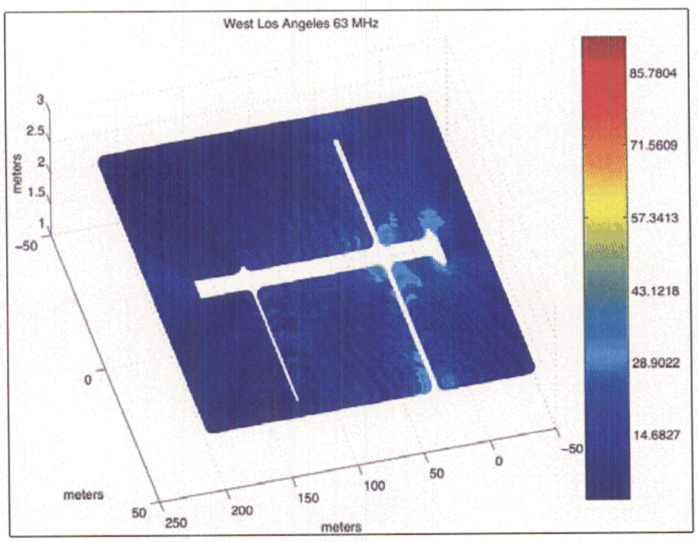

Figure 41: West Los Angeles–2 m AGL–Channel 3–Field in $\mu V/m$